Published in AJSE, Vol:22, Issue: 1
Received on 10th December 2022
Revised on 27th February 2023
Accepted on 30th April 2023

AIUB JOURNAL OF SCIENCE AND ENGINEERING
ISSN: 1608 – 3679 (print) 2520 – 4890 (Online)

Design and Analysis of IoT-based Remote Load Monitoring and Outage Management System

Ahmed Muntasir Anwar, Md. Rifat Hazari and Mohammad Abdul Mannan

Abstract- **Monitoring and analyzing the data to locate the fault and repair it prior to a total system collapse is a crucial tool for the functioning of a power system. The purpose of this work is to use this concept to design a control system that enables the monitoring of critical parameters governing the distribution of power; the management of outages via fault detection based on variations in Voltage, Frequency, and Current; and the protection of the circuit from significant occurrences through the isolation of the load from the utility and the flagging of information through feedback to the utility authority. The project incorporates cutting-edge technology for IoT applications, which communicates with the microcontroller to gather data at predetermined intervals and then stores that data with relevant timestamps in a cloud service for later retrieval and analysis. This breakthrough can potentially lessen reliance on human intervention and solve the whole outage scenario by facilitating two-way communication in which power and information are transferred between customers and utilities to maximize grid efficiency. The suggested architecture allows for smart, timestamped data monitoring, remote access, and historical data preservation, all contributing to an improved load profile. The proposed system's outage management system is built on intelligent fault detection using Voltage, Frequency, and current variation, followed by isolating the problematic part from the rest of the network, keeping an auto circuit recloser application in place prior to permanent isolation to minimize human intervention, flag outage information, and provide emergency backup during the shutdown time; this prevents the power grid from experiencing a complete blackout or blackouts.**

***Keywords*:** Electrical power system, microcontroller, wi-fi module, GSM module, remote data monitoring, demand side management, outage management system, IoT.

I. Introduction

The electrical grid is only one of humanity's many complex man-made constructions. A stable mode, multiple control loops, constant monitoring, rapid fault detection, and, if necessary, system isolation are essential to the reliable functioning of this crucial power supply.

Ahmed Muntasir Anwar is an Electrical Power Engineering Professional who earned his M.Sc. in EEE from American International University- Bangladesh's EEE department in Dhaka, Bangladesh. E-mail: muntasiranwar@gmail.com

Md. Rifat Hazari is a Senior Assistant Professor of the Department of EEE and Deputy Director of Dr. Anwarul Abedin Institute of Innovation, American International University-Bangladesh, 408/1, Kuratoli, Khilkhet, Dhaka-1229, Bangladesh. E-mail: rifat@aiub.edu

Mohammad Abdul Mannan is a Professor and Associate Dean of the Department of EEE, American International University-Bangladesh, 408/1, Kuratoli, Khilkhet, Dhaka-1229, Bangladesh. Email: mdmannan@aiub.edu

Because of this, monitoring and analyzing data to locate the fault and fix it before the system collapses is a vital tool for the operation of a power system.

Numerous studies have investigated the grid failure of any external supply source by detecting the variations in system characteristics, demonstrating the researchers' awareness of the critical nature of a reliable and stable power system. Frequency and voltage fluctuations are the most common causes of grid failure, upon which most studies and research are based. For this reason, the microcontroller controlling system consisting of a comparator set and a regular Arduino is used [1] to identify the cause of grid failure based on parameter fluctuations. In another study, researchers describe how to passively detect supply breakdown by monitoring microcontroller-based Frequency and Voltage deviations [2]. The under/over Voltage is monitored by a PIC microcontroller-controlled system through a voltage sensor and a series of comparators [3] for grid failure detection. Another approach is briefly addressed [4]; it monitors parameter changes at the feeder unit to identify synchronization failure and, by extension, various forms of islanding. A different studied system is built around an Arduino Uno microcontroller and provides GSM information through SMS to a selected person at the fault's location [5]. One more significant work was investigating a microcontroller AT89S52/AT89C51-driven system for detecting grid synchronization failure by gauging voltage and frequency change to prevent islanding states that might lead to grid breakdown [6]. The MCS-51 series of microcontrollers and op-amps are used to create a system that automatically disconnects the supply source from the load after detecting changes in voltage and frequency from any external supply source [7]. All of this research aimed to make the power dispatching task stable and secure by identifying faults in the network based on the fluctuation of critical parameters like voltage and frequency. Developing a fault detection system to identify grid synchronization failure by detecting limit breaches of grid Frequency & Voltage is a central focus of all this research as they aim to ensure the reliable day-to-day functioning of the power network. The grid must deliver electricity according to the grid code to provide a reliable power network for the many customers connected to it. A system to detect synchronization failure of any external supply source to the power grid on sensing anomalies in frequency and voltage is being developed as part of another significant project focusing on this issue. This system is based on a microcontroller of the 8051 families and Arduino and utilizes GSM technologies to monitor data in an HMI device [8].

The depletion of fossil fuel reserves has increased the urgency of the need to diversify grid-connected power. Introducing a "Smart grid" may resolve the problem by accommodating various Renewable energy sources and providing more innovative and cutting-edge technology to manage the variable power supply, which results in a sporadic generation. Avoiding total or partial power grid failure is a significant problem. Hence the current centralized distribution network must be turned into a more distributed and dynamic power network with a robust monitoring & information sharing network, enhanced load regulating & demand management choices. Power outages may occur when the electricity demand suddenly spikes due to abrupt changes in generation, the unpredictability of renewable energy supplies, weather, equipment failure, or rapid economic expansion. The electricity provider may effectively manage demand with the aid of Demand Side Management by incentivizing customers to alter their energy consumption levels and patterns. DSM encourages conservation, reduces utility bills, and improves grid performance, all while assisting customers in improving their efficiency. A two-way communication system is essential in DSM for the utility to plan the availability of power and the economic dispatch of the generation for the most efficient and cost-effective grid operation.

This research introduces a novel approach that may alleviate human requirements and resolve the whole outage scenario by establishing two-way communication to optimize the performance of a grid. The suggested model's intelligent monitoring of the timestamped system parameters, with remote access and historical data preservation, is invaluable for improving the load forecasting profile. By intelligently detecting faults through Voltage, Frequency, and current fluctuation, isolating the problematic portion from the rest of the system and flagging the outage information, attempting reconnection automatically, and providing an emergency backup source powered by any renewable energy resources, the suggested system may prevent power outages and blackouts. This designed system can give essential timestamped monitored data that can be accessed remotely and can also archive to generate an appropriate load profile, which in turn may support the modeling of Load Forecasting for a smooth and economic grid operation and can be utilized for establishing the Smart Grid network. These timestamped records may be used to reconstruct the cause of any power network issue, get insight into the state of the network during the fault, and inform the appropriate authorities on how to prevent such incidents in the future.

II. Proposed System Design

This project uses an ATmega-328PU microcontroller to prototype a module that monitors, detects, and isolates power supply faults to restore normal operations. A GSM module sends SMS notifications to designated contacts when a system fault occurs. An ESP-32 wi-fi module remotely monitors system parameters in a cloud system, preserving data for the study. An inverter circuit ensures power continuity during a projected device interruption. This microcontroller-based monitoring, detection, and protection System shuts off electricity and analyses disruptions. This section measures and computes signal parameters using voltage, current, and frequency sensing circuits. This module uses the government's grid code's pre-settle variation range of Voltage, Frequency, and Current to identify and isolate the load by tripping the relay for protection if the variation is beyond the permissible range. If the relay trips, the GSM module sends an SMS with fault information to a selected mobile number, allowing the designated service team to respond and solve the problem. The ESP-32 wi-fi module also connects to the ATmega-328PU microcontroller, receives voltage, current, frequency, and trip information at specified intervals, and uploads the data to an IoT-based cloud platform for analysis and storage. An embedded system using an Arduino Microcontroller, MOSFET-driven Half-Bridge inverter circuit, and DC power supply powers the consumer when the utility power fails (proposed to be connected to renewable energy).

The block diagram for the proposed system is divided into two sections: the first is for the measuring and monitoring system and the outage management system, and the second is for the inverter system that would provide emergency backup power in the event of a power loss.

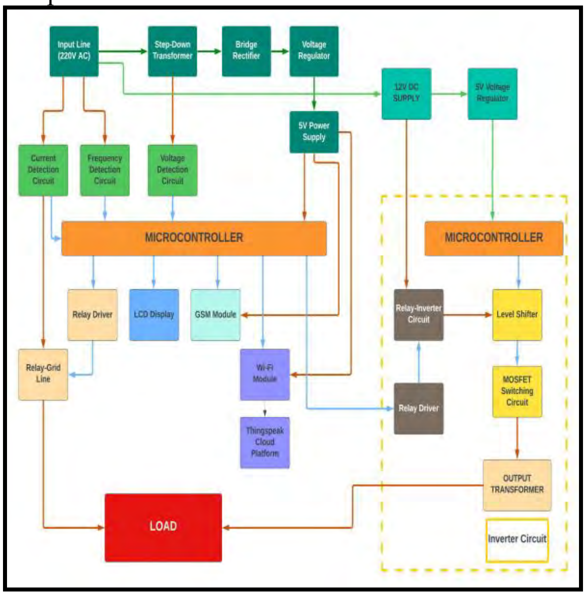
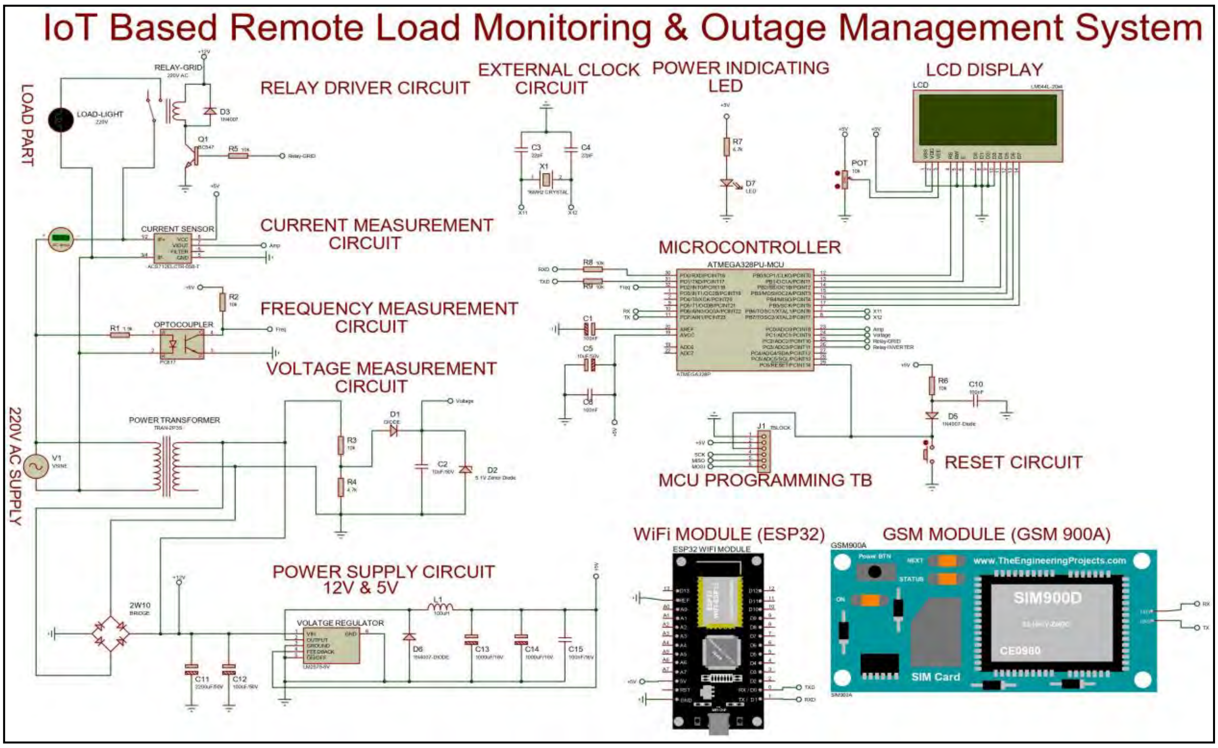
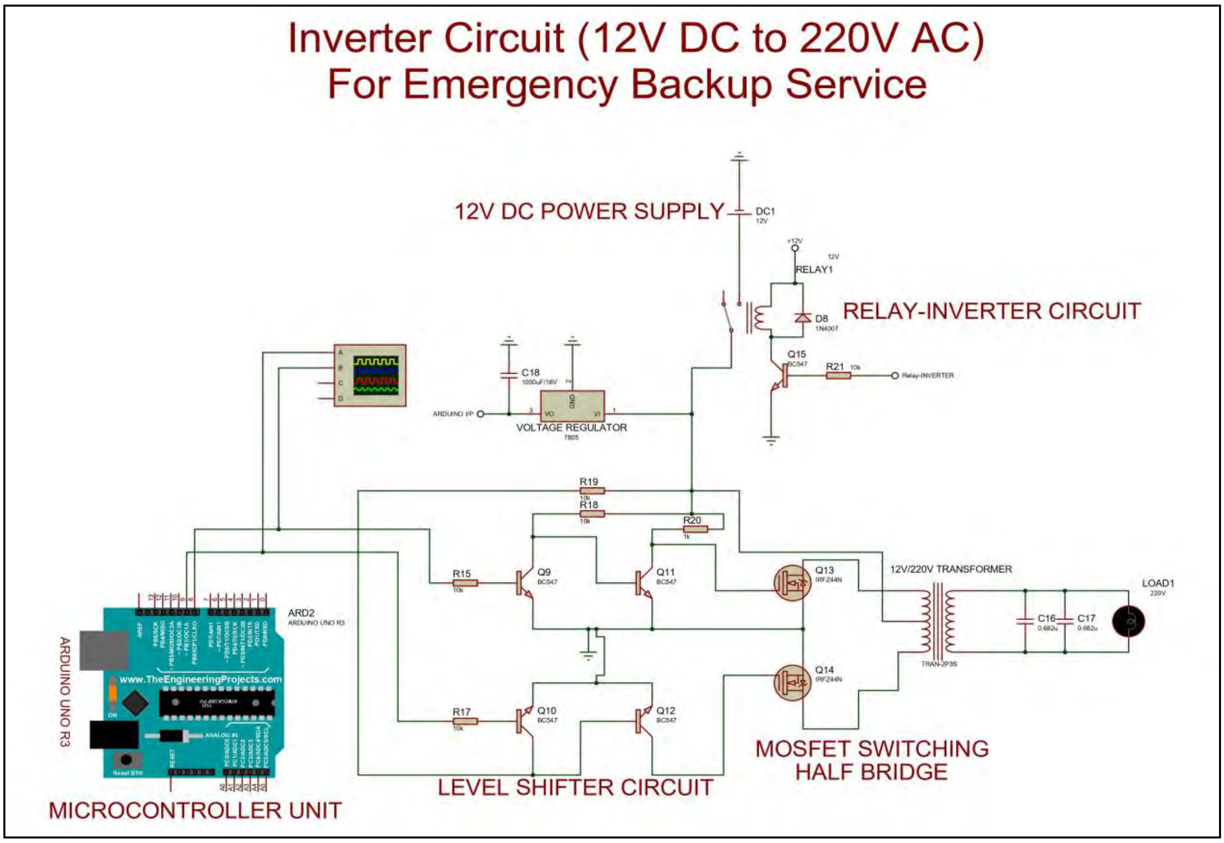


Fig. 1: System Block Diagram

Fig. 1 depicts the block diagram of the suggested system, divided into 07 (Seven) segments in the first part and 05 (Five) segments in the second part according to their respective operating principles. The planned systems are as follows, as shown in the block diagram: An Power Supply Unit, Sensor Unit, Microcontroller Unit, Relay Circuit Unit, Display Unit, GSM Module Unit, and Remote Data Monitoring Unit make up the Remote Monitoring &



(a) OMS Part



(b) Inverter part

Fig. 2: Circuit Diagram of the Proposed System

Outage Management System. The backup system's inverter circuit components include the microcontroller unit, the power supply unit, the switching and level shifting circuit, the inverter circuit's relay, and the output transformer.

The Circuit Diagram for the Proposed System is Depicted in Fig. 2(a) and (b), and it serves to Illustrate the Detailed Description of Each Component. The recommended system uses a step-down transformer, bridge rectifier, and voltage regulator to supply the modules with 5V DC. Filter capacitors enhance DC voltage and reduce ripple voltage in this case. When dealing with rectified DC output, an inductor is utilized to filter out the AC components.

The power supply rectifies and steps down the DC voltage before passing it to the voltage divider circuit, which feeds it to the ATmega328P-ADC PU's channels to maintain the signal within 5V. The microcontroller processes the digital signal into a voltage output.

The model uses a Hall effect–based Linear current sensor with 185mV sensitivity to monitor maximum 5A current. Hall effect sensors create electromagnetic fields that are transformed into voltages. The microcontroller's ADC analog input channels process the current sensor's output.

The suggested model uses an Optocoupler connected to the AC input and wired to the microcontroller's external interrupt Source Pin. This optocoupler isolates the high and low-voltage sides and converts the sine wave signal into a square wave logic signal for the microcontroller. An external interrupt triggers the Microcontroller's Timer module and determines the interval between interruptions by monitoring the optocoupler output's falling edge. The Microcontroller's Timer/Counter module determines the system's frequency using the inverse equation of time.

This design employs Microchip's high-performance, low-power ATmega328P-PU microprocessor, an 8-bit microcontroller with advanced AVR RISC architecture. The MCU's ADC determines line voltage and current. The ATmega328P microcontroller contains a Timer/Counter (TC) Module with a 16-bit counter and two 8-bit counters for frequency determination. The same microprocessor drives the display circuit, relays, wi-fi module data, and GSM module signals.

An electromechanical relay would control load and protect the circuit by making or interrupting the electrical connection. Because of its fast ON-OFF switching, an NPN transistor is usually the principal switching device. A "flywheel diode" dissipates energy from a relay coil across a semiconductor transistor. If the transistor switching circuit fails, the microcontroller drives the relay and isolates the circuit.

The Local HMI's 4x20 LCDs system displays status, error alerts, and measured data. The display is 5V-powered and has a variable resistor to regulate brightness. MCU-display code initializes the LCD library.

Dual-band GSM/GPRS modem SIM900A is the smallest and cheapest. AT Commands control this 5V module. When an issue is detected, the MCU triggers signal production and data transfer to the GSM module, which sends an SMS to a predetermined mobile number in the suggested system code. The microcontroller code provides SMS alert parameters for voltage, frequency, current, and other changes in the case of failure.

The Remote Data Monitoring Unit (RDMU) retrieves MCU data at predetermined intervals and publishes it in a web-based platform for remote access monitoring and preservation of historical data and online data display. The ESP-32 wireless module utilized here benefits IoT applications greatly. The ESP32 acts as a slave device to a host MCU to provide wi-fi capabilities through its UART ports, relieving the main application CPU of the communication stack. The Arduino IDE 1.8.19 program uploads the code that lets the ESP-32 talk to the MCU, collect data at regular intervals, and upload it to the cloud service (www.thingspeak.com) with time stamps.

The uploaded code provides WPS instructions and libraries to connect the ESP-32 to the internet and send data to a private channel on www.thingspeak.com. Thingspeak, a free online service, uploads sensor readings to the internet and shows the data in charts with a timestamp, allowing it to be viewed remotely, monitored at any time, and saved for future use. To communicate encrypted data with an ESP-32 using the suggested device's Unique ID & API Key supplied in the code, a private account is created at www.thingspeak.com, and a new channel is made with fields for Voltage, Frequency, Current, and Trip data.

The proposed backup system uses renewable energy. In the recommended arrangement, a 12V DC power supply powers the inverter circuit, which uses power devices, switching devices, and a transformer to convert DC power into AC power. A 12V/220V, 600VA Transformer steps up the power from the ON/OFF switching devices. Power MOSFETs maintain "ON/OFF" status. The output transformer's secondary windings' alternating voltage functions as an equivalent amplifier circuit, boosting the voltage to 220V AC. Centre tap transformer theory explains the push-pull behavior of the inverter circuit's output stage.

An Arduino Uno R3 follows the input supply's sine wave to create the SPWM signal. The power MOSFET gate drive signal is transmitted to the board's PB0 and PB1 pins.

The inverter circuit's Arduino board's 5V output may not be enough to drive the MOSFETs directly. A BJT-based level shifter boosts the gate drive voltage to 12V to minimize MOSFET overheating.

The transformer's output capacitors reduce alternating current jolts. The output capacitor is charged at varying rates according to the duty cycle, resulting in a smooth sine wave curve.

Fig. 3 discusses constructing an algorithm to drive the recommended module. The sensor circuit and microprocessor help the proposed system measure voltage, current, and frequency. The LCD displays measured data and the status of the associated circuit, and the cloud monitoring platform stores and remotely accesses them. Readings are compared to user-set National grid code criteria.

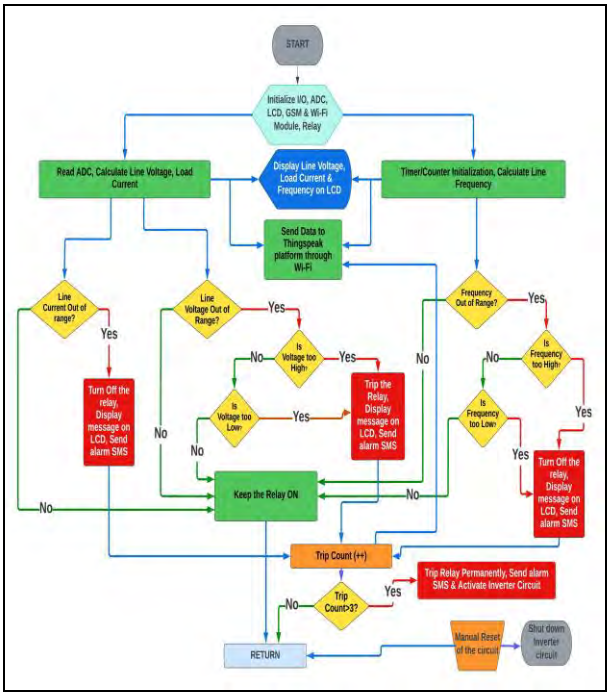


Fig. 3: System Flow Chart

The system continues operations or isolates the connected circuit depending on how these values depart from the preset fields. The recommended system is patterned after the Automated Circuit Recloser to ease dispatching, ensure safety, and reduce human interaction. The suggested system would monitor voltage, frequency, and load current to count fault-related trips. If the number of trips exceeds the user-defined criteria, the circuit is permanently isolated until the device is manually restarted after fixing the issue. The proposed system sends a fault-related text message to a given phone number when an issue occurs and requests feedback. The maintenance personnel may take action after receiving the last trip notification, saving time and effort. After the grid is permanently shut down, the emergency backup system keeps customers supplied during power outages during restoration. The backup system turns off automatically after a manual reboot.

The proposed system targets rural low-voltage, single-phase users. This system ensures the use of decentralized supply, such as solar power, as a backup supply, provides a required outage management system for individual customers, makes the distribution network more stable and secure, and provides bidirectional communication for transitioning from a traditional grid system to a smart grid. Remote data monitoring and archiving using IoT apps allow smart grid applications, including scenario reconstruction for analysis and enhancement, consumer load profile modeling, load forecasting, and generation schedule planning. Numerous tripping and reconnections reduce human work in the proposed system.

This system provides the necessary outage management system for individual consumers, transforming the distribution network into a more stable and secure network, establishing bidirectional communication to convert the conventional grid system into a smart grid, and ensuring the use of decentralized supply, such as solar power, as back up supply.

Remote data monitoring and archiving utilizing IoT apps gives the system a modern edge in employing smart grid applications, including reconstructing scenarios for analysis and improvement, modeling consumer load profiles, forecasting, and generating schedules.

III. Simulation Results

In this project, the circuit diagram and software simulation are modeled in Proteus 8.6 to analyze the output.

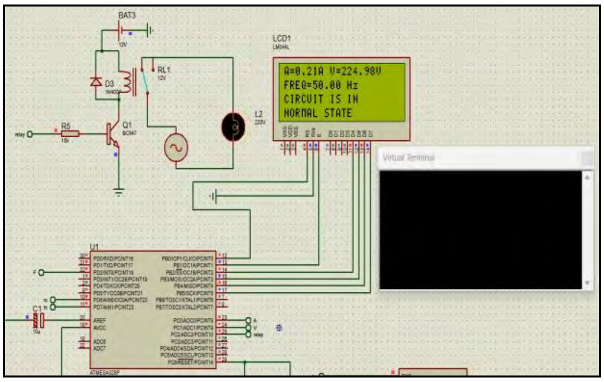


Fig. 4: Circuit in Normal Condition

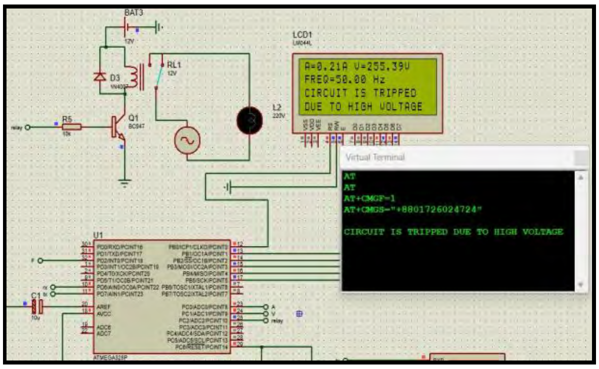


Fig. 5: Circuit Trip due to High Voltage (Corresponding SMS sent)

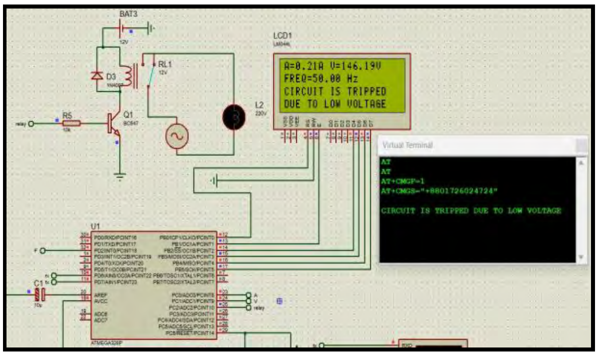


Fig. 6: Circuit Trip due to Low Voltage (Corresponding SMS sent)

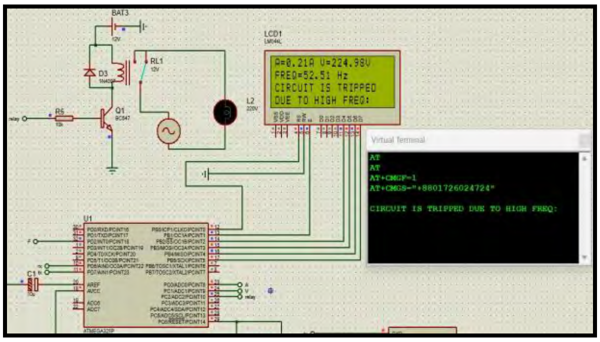


Fig. 7: Circuit Trip due to High Frequency (Corresponding SMS sent)

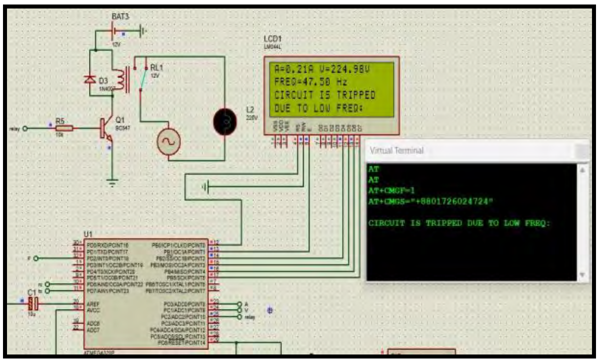


Fig. 8: Circuit Trip due to Low Frequency (Corresponding SMS sent)

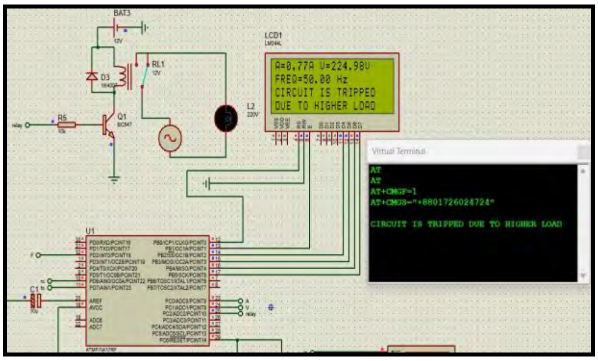


Fig. 9: Circuit Trip due to Higher Load Current (Corresponding SMS sent)

The proposed system's simulated output in a proteus environment is shown in Fig. 4–9, and its operating conditions are given in Table 1. The suggested approach yields promising results in simulation software. In addition, the system successfully mimics circuit separation through relay operations under fault circumstances and flagging options by sending alarm SMS messages.

Table 1: Circuit Operation Conditions

Condition	*High Limit*	*Low Limit*	*Circuit Condition*	*GSM Module*	*Wi-fi Module*
Voltage Fault Condition	>242KV	<198KV	Circuit Will Trip	SMS alert is sent to the designated mobile number.	The last Measured data is archived in the cloud backup
Frequency Fault Condition	>51Hz	<49Hz	Circuit Will Trip		
Current Fault Condition	>0.6Amp		Circuit Will Trip		
Safe Operation Conditions	198V≤Voltage≥242V 49Hz≤Frequency≥51 Hz Current≤0.6Amp		The circuit operates at Normal status	No SMS alert is Sent	Normal Data is monitored & sent to the Cloud Platform
Trip Count for the Main relay connecting the main supply	>3		The circuit is permanently tripped & backup support circuit starts.	SMS alert is sent to the designated person	Data is monitored & sent to the Cloud Platform

IV. Hardware Test Results

During the evaluation, the prototype was subjected to 60W, 100W, and 200W incandescent light loads, with the resulting output being monitored under four distinct operating conditions. The test results are shown in Table 2.

Table 2: Circuit Operational Conditions Testing

Connected Load	*Measured Voltage in Volt*	*Measured Frequency in Hz*	*Measured Current in Amp*	*Circuit Condition*
No Load	234.86V	50.51Hz	0.05A (AC)	Operating
60W Bulb	235.35V	50.56Hz	0.25A (AC)	Operating
100W Bulb	234.13V	50.85Hz	0.44A (AC)	Operating
200W Bulb	235.35V	50.89Hz	0.82A (AC)	Trip (first time) and SMS Sent
200W Bulb	235.35V	50.89Hz	0.82A (AC)	Trip (Second time) and SMS Sent
200W Bulb	236.33V	50.63Hz	0.82A (AC)	Trip (Third time) and SMS Sent
200W Bulb	236.33V	50.63Hz	0.82A (AC)	Trip permanently and SMS Sent
20W LED Light	244.10V	49.40Hz	5.99A (DC)	Inverter Circuit Started after the permanent trip of the first relay

A. Circuit Operation Under Normal Conditions:

Normal working characteristics of the circuit under no load circumstances and load situations are shown in Fig. 10 through Fig. 12. (While 60W and 100W bulbs are connected to the circuit). All three working states shown in Fig. 10–12 are supported by the proposed circuit, which monitors the parameters and sends the real-time data to the thinkspeak cloud platform through the built-in wi-fi module, as detailed in Table 2. For these conditions, the suggested solution enables the safe and reliable functioning of the grid to be maintained.

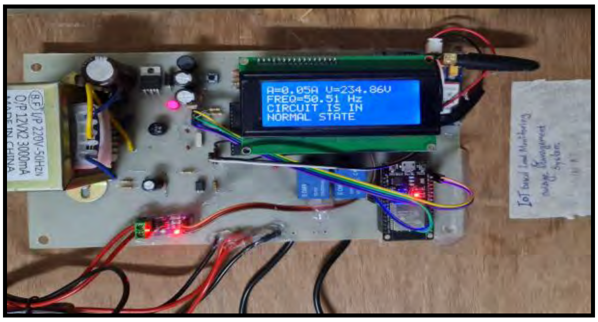


Fig. 10: Circuit Normal Condition while in No Load Condition.

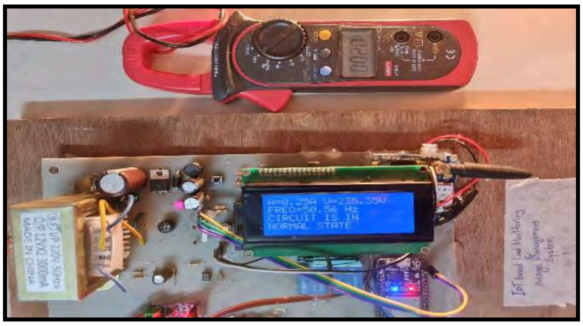


Fig. 11: Normal Circuit Condition while connected to a 60W Bulb

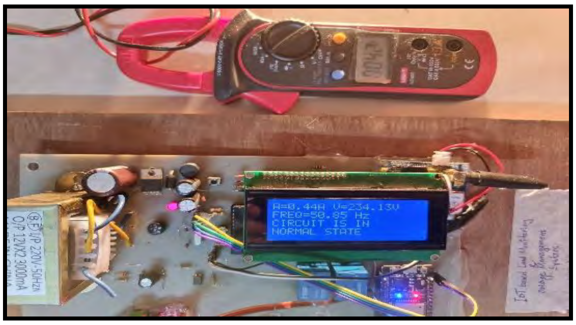


Fig. 12: Normal Circuit Condition while connected to a 100W Bulb

B. Circuit Operation Under Fault Condition:

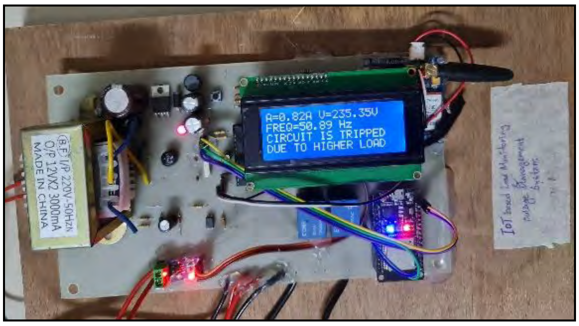


Fig. 13: Circuit Fault Condition while connected with a 200W Bulb

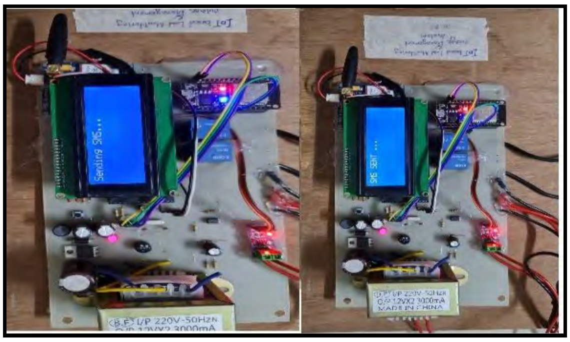


Fig. 14: SMS alert sent in progress to the designated mobile.

Fig. 15: Alert SMS Received by the Designated Mobile Number.

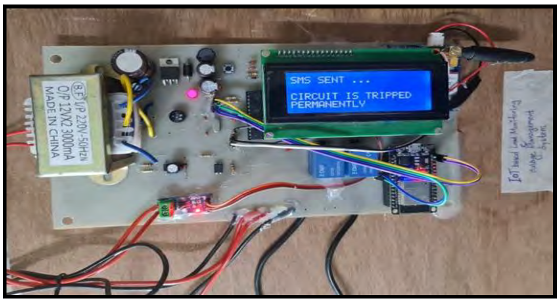


Fig. 16: The Circuit is tripped Permanently for Fault condition: Circuit Tripped with 200W light

With the 200W bulb plugged into the circuit, the overall current consumption limit was exceeded, the suggested mechanism was triggered, and the system tripped (Fig. 13). To prevent a widespread blackout, the grid immediately disconnected the load (as shown in Table 2). Instantaneously upon detecting the outage, the relay circuit was engaged, and an SMS was sent to alert and notify a specific team of people to come to fix the issue (Fig. 14 & 15). As part of the broader Demand Side Management methodology, this process is known as an Outage Management System. OMS is essential for controlling the Distribution system and preventing a synchronized breakdown of the grid by isolating the problematic section and reporting the trip information to the Utility authority for a more expedited maintenance and restoration process. Following the Auto Circuit recloser approach, the suggested system would attempt to reconnect the circuit three times before permanently tripping the system, enabling utility management to cut staffing costs without sacrificing service quality.

Once The ATmega328P-PU microcontroller is programmed to immediately transmit a high signal to the relay linked to the inverter circuit after the circuit has been permanently tripped after three failed attempts to reconnect. After the Arduino Board is switched on, it delivers the necessary Gate drive signal to each MOSFET, and the second relay begins running by switching the positive connection of the DC power supply. The prototype's integrated inverter circuit allows it to function with any renewable energy source that doesn't connect to the power grid. With the suggested system in place, grid dispatching operations may be relieved of some of their burdens, and the utilization of decentralized power sources can be guaranteed under this isolation condition mentioned in Table 2.

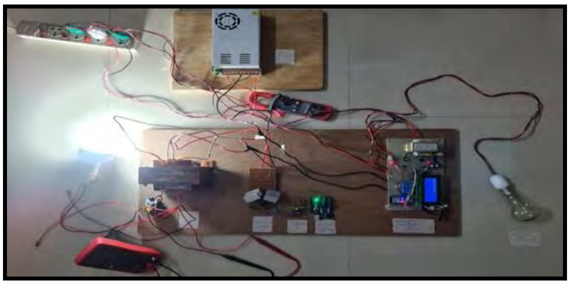


Fig. 17: The inverter Circuit is Turned 'ON' with a 20W LED light (left side) after the permanent trip of the Main relay

In the end, the 20W LED light connected to the secondary side of the transformer lights up when the half-bridge circuit constructed using MOSFETs begins switching at the necessary frequency (Fig. 17). In the case of a permanent main relay trip, the primary circuit is designed to restart receiving readings from the grid supply side and transmitting them to the cloud server through the wi-fi module after a brief delay (Fig. 18).

The utility authority may track how much time has passed after the problem was fixed because of this feature's ability to monitor the circuit's condition locally and remotely.

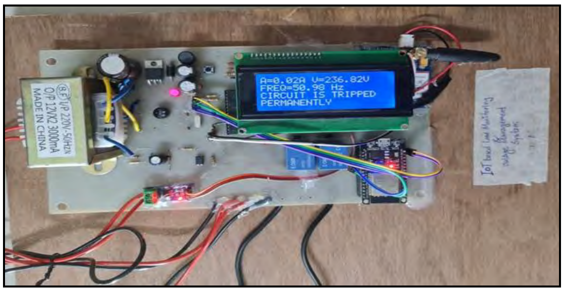


Fig. 18: Continuation of Measurement of the Main Supply after Permanent tripping of the Main relay.

Fig. 19: Inverter Output Parameters (Voltage, Current, Frequency & Output waveshape)

The inverter circuit's voltage, current, frequency, and output wave shape were measured and analyzed throughout the hardware testing phase to guarantee the system's reliability and effectiveness. During the hardware testing phase, the secondary voltage of the transformer was 244.1V, the DC input current was measured as 5.99A, and the frequency was 49.4Hz, all while powering a 20W LED light from the output (Fig. 19). This hardware verification helps the project achieve its goal of using a renewable energy source to power a backup supply system for use in case of an outage.

C. Remote Data Monitoring & Archiving

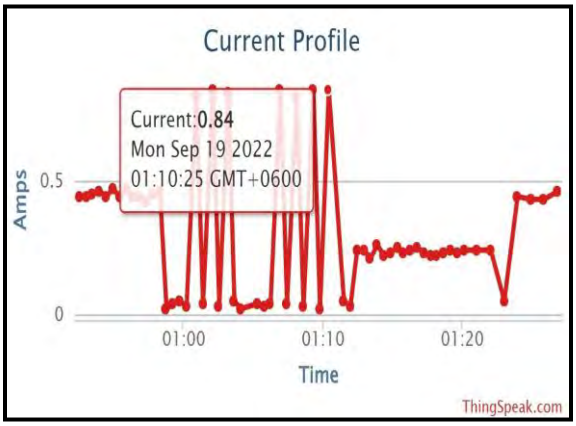


Fig. 20: Current data profile published on the www.thingspeak.com webserver.

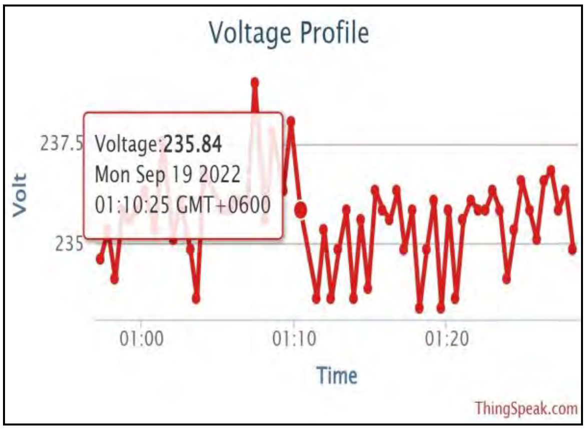


Fig. 21: Voltage data profile published on the www.thingspeak.com webserver.

The current consumer profile is shown in Fig. 20. This graph displays the typical load profile or utilization rate as a function of current. On September 19, 2022, at 01:10:25 (Bangladesh standard time: GMT+06), the consumer's load Current was 0.84A, which is more than the assigned load of 0.6A, while the rest of the time, the consumer's load pattern was below 0.5A.

Filed away in the web server database, the voltage profile is seen in Fig. 21. As of 01:10:25 September 19, 2022 (Bangladesh Standard Time, GMT+06), the consumer's Voltage profile was 235.84V, which is below the permissible voltage fluctuation threshold. As a result, the entire voltage profile remained within the grid's designated safe operating range.

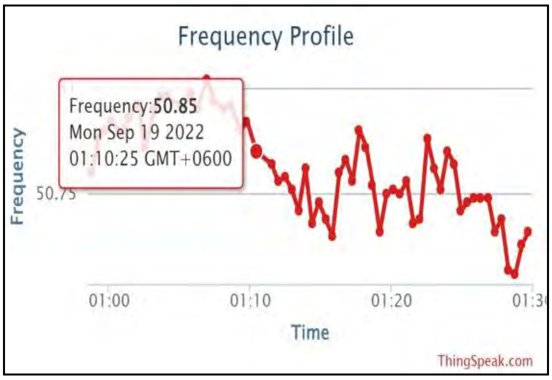


Fig. 22: Frequency data profile published on the www.thingspeak.com webserver.

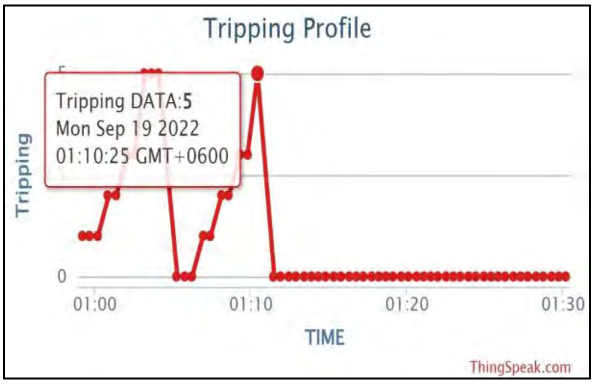


Fig. 23: Tripping data profile (For Main Relay) published on the www.thingspeak.com webserver.

The server-stored frequency data for the system is shown in Fig. 22. Parallel to the Voltage and current information for a specific consumer, all data are timestamped. This customer had a Frequency profile of 50.85Hz on September 19, 2022, at 01:10:25 (Bangladesh standard time, GMT+06). In general, the profile of frequencies stayed within the grid's designated safe operating range.

This Fig. 23 shows the Tripping Data profile stored on the web server. The tripping profile peak for this consumer occurred at 01:10:25 on September 19, 2022 (Bangladesh standard time: GMT+06), which resulted in the permanent tripping of the grid line. The circuit did not trip outside the period when it was reset after fault rectification.

It was determined via hardware testing and data saved on the www.thingspeak.com web server that the maximum voltage was 235.84V, the maximum current was 0.84A, and the maximum frequency was 50.85Hz on Monday, September 19, 2022 (Bangladesh standard time: GMT+06). According to Table 1, the load current incurred by the customer was 0.84A, which exceeded the permitted maximum. Even though the input voltage and frequency were within the permissible working range, the circuit still tripped as intended due to a load current usage limit violation. As can be seen in Table 2, the proposed model (prototype device) accomplished all of the project's objectives, including the detection of the fault based on the variation of parameters like voltage, frequency, and load current, the isolation of the load, and the sending of alert SMS to the designated team. All the information saved on the web server is dated so that utility authority can determine the consumer's usage in real-time right around the Fault time. With the information gained from these studies, a good load profile/pattern of the consumers may be built, which is essential for the efficient, cost-cutting functioning of a power network, whether it is managed by a Distribution Management System (DMS) or an Energy Management System (EMS).

Archive data may be used to successfully reconstruct the fault for further investigation and service improvement to avoid a partial or total system blackout. This is shown in Fig. 24, which shows the process of retrieving historical data from Thingspeak's cloud storage to recreate prior scenarios, analyzing fault conditions (for example, while testing the prototype device tripped on Monday, September 19, 2022 (Bangladesh standard time: GMT+06) owing to increased uses of load current), or determining the end user's optimal load profile or pattern to ensure a stable and dependable grid.

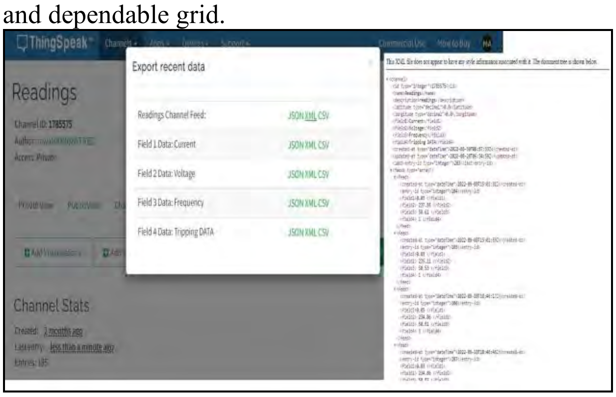


Fig. 24: Data Retrieval Process from the www.thingspeak.com webserver.

The results of the tests show that the suggested model's prototype operates as intended. The prototype device performs continuous monitoring of the parameter, successfully executing the Outage Management System, and archiving the timestamped data to a web server through a wi-fi module, which can be accessed remotely from anywhere for analytical purposes to develop a perfect load profile of the end consumers, and eventually validating the two-way communications for constructing a good DMS/EMS.

V. Evolution via Comparison

With the help of data monitoring and archiving, which can reveal details about End-user Load behavior and Usage Patterns helpful in modeling the DSM, the project intends to realize its aims in support of the deployment of DMS. In contrast, the goals of prior studies and research were to detect grid synchronization failure via voltage and frequency fluctuation and then, based on that detection, to isolate the load to ensure grid safety [2], [6], [7], [8], [9]. Recent 2022, 2020, 2018, and 2019 research examines several approaches to measuring voltage and frequency close to the point of failure; the suggested module then uses this information to identify and eliminate the offending component. In contrast with the older studies, this proposed study builds on the notion of detecting grid synchronization failure owing to voltage and frequency failure, making it more robust via evolutions at the hinge end, such as measuring load current for OMS implementation, employing IoT platforms and devices for remote monitoring and historical data archiving and establishing a comprehensive Data Acquisition and Control system to serve the dynamic data needs of SCADA-related applications and OMS in real-time. In addition to providing the trustworthy information, historical storage, and remote access, the suggested system guarantees two-way communication between the consumer and the utility provider. This suggested project employs the unique identity (UID) through API key, created by the state-of-the-art IoT device ESP32, which provides more robust security and quality data transmission. In addition, this device assures more advanced technologies supported by the IoT platform. This project contrasts the system exhibited in previous studies, based on a microcontroller of the 8051 families and/or Arduino, and leverages GSM technologies to monitor data in an HMI device [8].

The feasibility of this study is further bolstered by the fact that the Distribution system Demand response (DSDR) is an ideal mechanism for keeping the electricity network under manageable conditions. This project can assist homeowners in managing their energy use and improving their electrical efficiency through the Home Energy Management System. Consumers can install a supplemental Solar Power System with this project to meet their demands during the proposed system's load control (tripping). Compared to competing systems on the market, this project provides a more cost-effective option for Distribution End customers. Compared to older research focused on defect detection and load separation, this newer study has a significant advantage because of its cutting-edge features. For its intelligent sensor-based circuit, cutting-edge components like ESP32 & GSM module, and use of an intelligent algorithm for connecting consumers to the utility through several advance software like OMS, ACR, SCADA, HEMS, Data Reconstruction, Load forecasting & generation Scheduling, the proposed device can be seen as the smart tools for the distribution network, making the Total Grid Dispatching operation more dependable, safe, and cost-effective. The research set out a method to protect and simplify grid operations while raising consumer awareness.

VI. Conclusions

Improving the reliability and performance of the electricity grid is an issue that places significant demands on academics. The proposed project seeks to better digitalize an Energy monitoring system with sophisticated but labor-intensive features, including failure detection, SMS alerts, remote data monitoring, and archival capabilities for distribution End customers. From a service provider's perspective, this tool may speed up maintenance and troubleshooting while reducing the time spent clearing faults and restoring circuits. Overcoming the obstacles of transforming our traditional power grid system into a Smarter one with lower energy wastages & increased dependability & secure network is the primary motivation for this project's implementation, which involves the introduction of Internet of Things (IoT) technologies and the usage of other state-of-the-art, current technology-supported ICs. Contest for a better-performed & uninterrupted power network is a highly demanding & challenging topic for researchers. The proposed project aims to achieve the target of a better digitalization of an Energy monitoring system by including advanced yet demanding features like detecting faults, sending alert SMS, providing remote data monitoring, and archiving facilities to distribution End consumers. Also, from the point of view of a service provider, this device can reduce human involvement at the initial fault-finding stage by an effort to restore the circuit automatically and alert in time if not rectified to accelerate the maintenance & troubleshooting work and reduce the fault clearing as well as circuit restoration work. Implementation of this Project is a dedicated effort to introduce Internet of Things (IoT) technologies and uses of other state-of-the-art modern technologically supported ICs to overcome the challenges of converting our conventional power grid system into a Smarter one with reduced energy wastages & improved reliability and secure network.

References

[1] P. Pandey, S. K. Sharma, "Detecting Power Grid Synchronization Failure on Sensing Bad Voltage or Frequency," International Journal for Scientific Research & Development, Vol. 6, No. 01, pp. 1170-1172, 2018.

[2] A. P. Singh, K. Ashutosh, S. Singh, M. A. Aggarwal, Student, "Detection Of Power Grid Synchronisation Failure On Sensing Frequency And Voltage"- International Journal of Advanced Research in Computer and Communication

Engineering, Vol. 11, No. 3, March 2022, DOI: 10.17148/IJARCCE.2022.11304.

[3] A. R. Inntiaz, M. Maaz, J. Varalakshmi, H. Kousar, H. Reddy, “Detecting Power Grid Synchronisation Failure on Sensing Frequency or Voltage Beyond Acceptable Range” International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 5 Issue 4, April 2017.

[4] Mohit Gera[1], Vikram Singh[2], Ram Kr. Pandey[3], Sonu Jaiswal[4], "Detection of power grid synchronization failure," - International Journal of Current Trends in Engineering & Research (IJCTER), e-ISSN 2455‐1392, Volume 3 Issue 5, May 2017 (pp. 103‐106.)

[5] B. N. Sarvani, B. V. Thulasi, K. Rahul, K. S. Kumar, V. D. S. Varma, “Detection of power grid synchronization failure on sensing frequency and voltage beyond the acceptable range and load protection” International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 07, July -2017.

[6] B. Naik, G. Shilpa, O. D. D’souza, B. P. Manjunatha, “Identifying The Frequency And Voltage Level At The Grid Connected Synchronisation Failure,” Journal of University of Shanghai for Science and Technology, Volume 22, Issue 10, October 2020.

[7] S. Singh, G. Shripad, G. Desai, “Detection Of Power Grid Synchronisation Failure By Monitoring Frequency And Voltage Using Embedded System”- International Journal of Engineering Development and Research (www.ijedr.org), ISSN: 2321-9939, the Year 2020, Volume 8, Issue 4, (Page-314-317).

[8] B. G. Naik, P. Sagar, M. J. Rezaee, D. Rasa, J. K. Vinod, “Power Grid Synchronization Failure Based On Voltage and Frequency Variations beyond Limit,” Journal of Engineering Research and Application www.ijera.com, ISSN: 2248-9622 Vol. 9, Issue 6 (Series -II) June 2019, (Page 77-81).

[9] M. S. Khande, V. Suraj, R. Radhesham, S. Shubham, “A Grid Synchronisation Failure Detecting by Sensing Frequency & Voltage’’ IJARIIE-ISSN(O)-2395-4396, www.ijariie.com, Vol-4 Issue-3, 2018 (Page-1497-1499).

Ahmed Muntasir Anwar was born in Chittagong, Bangladesh, in 1986. He received his B.Sc. Engg. and M.Sc. Engg. Degrees in Electrical and Electronic Engineering from American International University-Bangladesh (AIUB) in January 2008 and August 2022, respectively. In 2009, he joined Tokai Power Product Ltd as a Service Engineer, and in 2015 joined GE T&D India Ltd. as Engineer, EMS/SCADA. Since August 2021, he has been with GE T&D India Ltd. as Deputy Manager, EMS/SCADA, and posted as an EMS expert at National Load Despatch Centre (NLDC), PGCB. He is working with advanced SCADA and EMS-related application implementation, research & training. His research interests include Electrical Power, Grid Operation, and EMS/DMS implementation and applications. Ahmed Muntasir Anwar is a Member of the Institution of Engineers, Bangladesh & Licensed Electrical Supervisor (Category: ABC) granted by the Electricity Licensing Board, Bangladesh.

Md. Rifat Hazari received his B.Sc. Engg. and M.Sc. Engg. Degrees in Electrical and Electronic Engineering from American International University-Bangladesh (AIUB) in August 2013 and December 2014, respectively and Ph.D. Degree in Energy Engineering from Kitami Institute of Technology (KIT), Japan, in March 2019. He served as an Assistant Professor and Lecturer in Electrical and Electronic Engineering department at AIUB. Currently, he is working as a Deputy Director of Dr. Anwarul Abedin Institute of Innovation, AIUB, and Senior Assistant Professor in the Electrical and Electronic Engineering department at AIUB. He received the MINT (Academic Excellence) Award 2017 from KIT for the outstanding research of 2017 academic year, Best Paper Award in the Australasian Universities Power Engineering Conference 2017, Melbourne, Victoria, Australia and Best Presentation Award in the IEEJ Branch Convention 2017, Hakodate, Japan. He has published more than 65 articles in different journals and international and national level conferences. He has been an invited speaker at many universities and workshops. His research interests are renewable energy systems (especially wind power & photovoltaic power systems), power system stability and control, microgrid and hybrid power systems, HVDC system, analysis and control of rotating electrical machines. Dr. Hazari is a member of IEEE and IEB.

Mohammad Abdul Mannan was born in Laxmipur, Bangladesh on January 01, 1975. He received his B. Sc. Eng. Degree from Rajshahi University of Engineering and Technology (RUET former BITR), Bangladesh, in 1998, and Masters of Eng. and Dr. of Eng. degrees from Kitami Institute of Technology, Japan, in 2003 and 2006 respectively, all in electrical engineering. He then joined in the American International University Bangladesh (AIUB) as an Assistant professor in May 2006. He served in AIUB as an Associate Professor from December 2013 to November 2016. Now he is working as a Professor and Associate Dean of the Faculty of Engineering in AIUB. His research interests include electric motor drive, power electronics, power system, wind generation system and control of electric motor, power electronic converters, power system, and wind generation system. Prof. Dr. Mannan is a member of the IEB and IEEE.